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Prediction Model for Virtual Machine Power Consumption in Cloud Environments

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Abstract

Power consumption has become a crucial issue in cloud computing environments because of environmental and financial concerns. It is necessary to estimate individual virtual machine power consumption to enforce efficient power aware policies in cloud. Existing solutions are built on linear power models to infer power consumption through VM resource utilization. However, linear models do not capture dependencies among multiple parameters and hence they do not ensure prediction accuracy across multiple workloads. In this paper, a non-linear support vector regression based power model using performance monitor counters is proposed to predict individual virtual machine power consumption. Experimental results with various standard benchmark workloads demonstrate that the prediction accuracy of proposed approach is better than the existing linear regression based power model.

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Keywords: Cloud Computing; Virtual Machine; Power Consumption; Power Prediction Model; Performance Monitor Counter.

1. Introduction

Cloud computing is an important computing paradigm which facilitates dynamic flexible provisioning of services over the internet[1]. In cloud environment, power consumption has become a critical issue because of an operational expenditure as well as environmental impact due to CO_2 emissions. It is evident from existing literature that operational expenditures for powering and cooling of cloud data center resources will soon exceed the acquisition cost[2]. Hence, it is essential to enforce power aware solutions in cloud computing environment.

Most of the existing power aware solutions employ external hardware power meter to estimate the power consumption of whole server. However, measuring individual virtual machine (VM) power consumption is inevitable for implementing efficient power aware resource provisioning and pricing techniques in cloud environment. Moreover, it is very difficult to estimate individual VM power consumption in a shared virtualized environment.

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In existing literature, the linear models are used to deduce individual VM power consumption via VM resource utilization or hardware Performance Monitor Counters(PMC)[3,4,5,6,7,8]. However, the metrics used in the power models are correlated with each other. For example, the metrics of CPU utilization may be highly correlated with the metrics of memory utilization, since overwhelming of memory usage would lead to more CPU resource usage. The existing linear models do not capture the dependencies among the metrics which not only decreases the accuracy but also increases the complexity of power prediction.

In order to mitigate this issue, in this paper, a non-linear based Support Vector Regression (SVR) model using hardware PMC is proposed for accurate estimation of VM power consumption. SVR is used to model complex higher dimensional real-world problems with limited training samples. The hardware PMC events are used to accurately capture the VM resource utilization across multiple heterogeneous platforms. Experimental results with various benchmark workloads demonstrate that the proposed power model improves the accuracy of prediction than the existing linear regression based power model.

The rest of this paper is organized as follows. Section 2 reviews the related work regarding VM power model. Section 3 presents the details of the proposed power model. Section 4 illustrates the experimental results and finally, Section 5 concludes the paper.

2. Related Work

Modeling power consumption in virtualized environments is an active research topic. Many research works addressed the issue of per-VM power modeling. Kansal et al.[3] proposed a joulemeter VM power metering approach without guest OS modification. CPU, memory and disk components were considered for modeling power consumption. This approach was extended to provisioning process in virtualized environments. Krishnan et al.[4] proposed a VM power consumption model using two hardware PMC events such as instruction retired (inst_ret/sec) and LLC (Last Level Cache) misses for modeling power consumption of CPU, and memory. Cherkasova et al.[5] proved that I/O virtualization process consumes more power because of its CPU resource demand.

Bohra et al.[6] proposed four dimensional linear weighted regression based power model by correlating the power consumption of different components such as CPU, memory, cache, and disk. Bircher et al.[7] used hardware PMC events for modeling both server and desktop machines power consumption. Their experimental results demonstrated that selecting suitable hardware PMC events are crucial for building power models.

Bertran et al.[8,9] presented experimental study on investigating the effectiveness and accuracy of PMC based power models in both virtualized and non-virtualized environments. Jiang et al.[10] proposed a Look-Up Table (LUT) method to estimate the power consumption for different CPU and memory states. Though LUT method is flexible and easy to implement, it requires large memory to store LUT for each VM. Roberto et al.[11] provided the empirical investigation for power consumption of virtualization technologies. Chonglin et al.[12] employed a decision tree approach for modeling VM power consumption.

Most of the above works used linear models to estimate power consumption. However, the linear models do not capture the dependency among model parameters which results in inaccuracy of power prediction. Hence, the proposed approach employed non-linear SVR regression model for power prediction, thereby accurately capturing the effects of power consumption via hardware PMC events.

3. Proposed System Model

This section details the proposed system architecture for estimating an individual VM power consumption. The proposed model runs on top of Xen virtualized environment and it is based on black box method which collects modeling information from each VM without guest OS modification. The overall architecture of the proposed system is illustrated in Figure 1 and its major components are described as follows:-

- **Profiler**: -This module periodically profiles hardware PMC events of each VM for every sampling period. The hardware PMC events facilitate monitoring resource usage of each sub components (CPU, RAM, Cache, and Disk) which are highly correlated with total system power consumption. When a physical server is powered on, the PMC events will gather all system-level events which are triggered by various components. In